Improving Hospital Quality and Costs in Nonoperative Traumatic Brain Injury
The Role of Acute Care Surgeons

Bellal Joseph, MD; Viraj Pandit, MD; Ansab A. Haider, MD; Narong Kulvatunyou, MD; Bardiya Zangbar, MD; Andrew Tang, MD; Hassan Aziz, MD; Gary Vercruysse, MD; Terence O’Keeffe, MD; Randall S. Freise, MD; Peter Rhee, MD

IMPORTANCE  The role of acute care surgeons is evolving; however, no guidelines exist for the selective treatment of patients with traumatic brain injury (TBI) exclusively by acute care surgeons. We implemented the Brain Injury Guidelines (BIG) for managing TBI at our institution on March 1, 2012.

OBJECTIVE  To compare the outcomes in patients with TBI before and after implementation of the BIG protocol.

DESIGN, SETTING, AND PARTICIPANTS  We conducted a 2-year analysis of our prospectively maintained database of all patients with TBI (findings of skull fracture and/or intracranial hemorrhage on an initial computed tomographic scan of the head) who presented to our level I trauma center. The pre-BIG group included patients with TBI from March 1, 2011, through February 29, 2012, and the post-BIG group included patients from July 1, 2012, through June 30, 2013.

MAIN OUTCOMES AND MEASURES  The primary outcome measures were patients with repeated computed tomography of the head and neurosurgical consultations. Secondary outcome measures were findings of progression of intracranial hemorrhage on repeated computed tomographic scans, neurosurgical intervention, hospital admission, intensive care unit admission, hospital and intensive care unit length of stay, 30-day readmission rate, and hospital costs per patient.

RESULTS  A total of 796 patients (415 in the pre-BIG group and 381 in the post-BIG group) were included. There was a significant reduction (19.0%) in the rate of neurosurgical consultation (post-BIG group, 273 patients [71.7%]; pre-BIG group, 376 [90.6%]; P < .001), repeated computed tomography of the head (post-BIG group, 255 patients [66.9%]; pre-BIG group, 381 patients [91.8%]; P < .001), hospital (post-BIG group, 330 [86.6%]; pre-BIG group, 398 [95.9%]; P < .001) and intensive care unit admission (post-BIG group, 202 [53.0%]; pre-BIG group, 257 [61.9%]; P = .01), hospital length of stay (post-BIG group, 5.4 [4.5] days; pre-BIG group, 6.1 [4.8] days; P = .03), and hospital costs per patient ($4772 per patient; P = .03) with implementation of BIG. There was no difference in the in-hospital mortality rate (post-BIG group, 62 patients [16.3%]; pre-BIG group, 69 patients [16.6%]; P = .89), progression of intracranial hemorrhage on repeated scans (post-BIG group, 41 patients [10.8%]; pre-BIG group, 59 patients [14.2%]; P = .14), neurosurgical intervention (post-BIG group, 61 patients [16.0%]; pre-BIG group, 59 patients [14.2%]; P = .48), and 30-day readmission rate (post-BIG group, 31 patients [8.1%]; pre-BIG group, 37 patients [8.9%]; P = .69) after implementation of BIG.

CONCLUSIONS AND RELEVANCE  Implementation of BIG is safe and cost-effective. BIG defines the management of TBI without the need for neurosurgical consultation and unnecessary imaging. Establishing a national, multi-institutional study implementing the BIG protocol is warranted.
Traumatic brain injury (TBI) is a major medical and socioeconomic problem that affects 1.7 million people and results in more than 50,000 deaths annually. According to the US Centers for Disease Control and Prevention, the incidence of TBI-related emergency department visits and hospitalizations has increased by 20% from 2002 through 2006. Along with the loss of life and long-term disability, TBI costs up to 10% of the total health care budget, which accounts for nearly $30 billion annually. The initial diagnosis of TBI on a computed tomographic (CT) scan of the head is often followed by intensive care unit (ICU) admission, neurosurgical consultation, and repeated imaging. However, recent publications now support selective treatment of these patients. 

Acute care surgeons treat patients with TBI in the acute phase of trauma and form an integral component of their nonoperative treatment. Ninety percent of patients with TBI are treated nonoperatively, and there is a paucity of well-defined guidelines that highlight the role of acute care surgeons in the nonoperative management of TBI. Moreover, with advancements in CT scanners, the number of patients presenting to emergency departments with miniscule intracranial bleeds is increasing, leading to a rising number of neurosurgical consultations. These consultations, however, rarely alter the course of treatment of patients who present with normal neurologic examination findings and miniscule intracranial hemorrhage (ICH). In an effort to standardize the need for neurosurgical consultation and repeated CT scans of the head (RHCT) in patients with TBI, our institute formulated the Brain Injury Guidelines (BIG) based on a retrospective analysis of nearly 3000 patients with TBI who presented to our level I trauma center. These guidelines were based on patients’ medical history and findings from neurological examination and initial CT of the head. These guidelines, which were formulated in collaboration with our neurosurgical colleagues, addressed the role of the acute care surgeon in the management of TBI and had the potential to reduce the burden of nonoperative TBI on our neurosurgical colleagues. These guidelines were formally implemented on March 1, 2012; since then, we have been treating our patients with blunt TBI based on these guidelines. The aim of this study was to compare the outcomes of patients with TBI before and after implementation of the BIG protocol.

Methods

After approval and waiver of consent from the Institutional Review Board at the University of Arizona College of Medicine, we conducted a 2-year (pre- and post-BIG) analysis of our prospectively maintained database of all patients with TBI who presented to our level I trauma center. A waiver of patient consent was obtained because the BIG protocol was implemented as an institutional policy for management of TBI. The BIG protocol was implemented at our trauma center on March 1, 2012. The pre-BIG group included patients with TBI from March 1, 2011, through February 29, 2012, and the post-BIG group included patients from July 1, 2012, through June 30, 2013. The period from March 1, 2012, through June 30, 2012, was excluded from the analysis owing to excessively low compliance with the BIG protocol during the initial training period.

Inclusion and Exclusion Criteria

Patients with a blunt mechanism of trauma who had an ICH and/or a finding of skull fracture from an initial CT scan of the head were included in the study. We excluded patients who were transferred from other institutions, underwent emergency neurosurgical intervention, or were dead on arrival.

Data Collection

The following data points were prospectively recorded for each patient: patient demographics (age, sex, and mechanism of injury); vital parameters on presentation, including systolic blood pressure, heart rate, and temperature; Glasgow Coma Scale (GCS) score; neurological examination findings on presentation; intoxication (drug or alcohol); details regarding antplatelet and anticoagulation therapy; intubation; loss of consciousness; findings from an initial CT scan of the head (type and size of ICH); reasons for and findings from an RHCT; neurosurgical consultation; neurosurgical intervention details; hospital and ICU length of stay; discharge disposition; GCS score at discharge; and in-hospital mortality rate. The 30-day readmission rate was assessed by reviewing electronic medical records for hospital admissions within 30 days of the initial discharge. The Injury Severity Score and head Abbreviated Injury Scale score were obtained from the trauma registry.

Formulation of BIG

We developed BIG based on patients’ medical history (antiplatelet or anticoagulation therapy, loss of consciousness, and intoxication), findings from physical examination (focal neurological examination, pupillary examination, and GCS score on admission), and CT scan findings (size and location of ICH and type of skull fracture). Patients had to meet all the criteria for categorization into BIG 1 or BIG 2 (Table 1). Failure to meet even 1 criterion (in BIG 1 or BIG 2) categorized the patient into the BIG 3 category and altered the treatment plan for the patient based on the BIG 3 category.

Table 1 describes the 3 categories of brain injury guidelines. Patients who were categorized as BIG 1 (minor head injury) had normal findings on neurological examination, were not taking any antplatelet or anticoagulation medications, and had miniscule findings on an initial CT scan of the head. We proposed a 6-hour period of observation in the emergency department for patients who were categorized as BIG 1 without the need for neurosurgical consultation or an RHCT scan. The BIG 2 category was composed of moderately injured patients with a nondisplaced skull fracture and/or a localized ICH of 5 to 7 mm. Patients who were categorized as BIG 3 had a severe head injury, and the optimal therapeutic plan for these patients consisted of hospitalization, neurosurgical consultation, and a follow-up RHCT scan. Patients who were categorized as BIG 3 had at least 1 of the following high-risk features: an abnormal neurological examination finding, intoxication, antplatelet or anticoagulation medication use, concerning CT scan findings (displaced skull fractures, diffused subarachnoid hemorrhage, multiple types of bleeding, or an ICH ≥ 8 mm).
Patients who could not be examined and those who were intubated were also categorized as BIG 3. The compliance rate was defined as the percentage of patients in each BIG category for whom the predefined protocol for management (RHCT scan or neurosurgical consultation) was appropriately followed.

**Study Protocol**

1. After implementation of BIG, patients with suspected TBI underwent an initial CT scan of the head; those with an intracranial injury were evaluated by the trauma surgeon.
2. Patients were categorized into 3 BIG categories based on patients’ medical history and findings from neurological examination and the initial CT scan of the head, as assessed by the on-call trauma team.
3. Patients in the BIG 1 category were observed for 6 hours without neurosurgical consultation and had no RHCT. We defined abnormal neurological examination findings as altered mental status, focal neurological deficits, and an abnormal finding from pupillary examination.
4. Patients in the BIG 2 category were observed for 24 hours without an RHCT scan or neurosurgical consultation.
5. Neurological examination was conducted every 2 hours. Patients who had findings of deterioration on clinical examination were upgraded to a higher category, warranting an RHCT scan and neurosurgical consultation.

**Outcome Measures**

Patients were stratified into 2 groups: pre- and post-BIG. The primary outcome measures were patients with RHCT scans and neurosurgical consultations. Secondary outcome measures were findings of progression of ICH on RHCT, neurosurgical intervention based on hospital admission, ICU admission, hospital and ICU length of stay, 30-day readmission rate, and hospital costs per patient.

A single investigator (B.J., a trauma surgeon) reviewed the CT scans after the attending radiologist’s reading for the type and size of ICH. Neurosurgical intervention was defined as craniotomy and/or craniectomy or intracranial pressure monitoring.

**Statistical Analysis**

Data were reported as mean (SD) for continuous variables, median (range) for ordinal variables, and proportion for categorical variables. We used the Mann-Whitney test for nonparametric continuous variables and an unpaired 2-tailed t test for parametric continuous variables to explore for differences between the 2 groups (pre- and post-BIG). We used the \( \chi^2 \) test to identify differences in outcomes between the 2 groups for categorical variables. Ordinal variables were compared using the median test. For our study, we considered \( P < .05 \) statistically significant. All statistical analyses were conducted using SPSS, version 21 (IBM).

**Results**

A total of 796 patients (415 in the pre-BIG group and 381 in the post-BIG group) with TBI were included in our study. The mean age was 39.5 (24.7) years, 528 patients (66.3%) were male, the median GCS score on admission was 13 (interquartile range, 8-15), and the median head Abbreviated Injury Scale score was 2 (interquartile range, 2-3). Overall, 567 patients (71.2%) had loss of consciousness and 165 (20.7%) had abnormal neurological findings on examination. The 2 groups were similar in demographics, preadmission antiplatelet and anticoagulant use (\( P = .23 \)), blood pressure level on admission (\( P = .43 \)), mechanisms of injury (\( P = .24 \)), and head Abbreviated Injury Scale score (\( P = .74 \)). Most patients were classified as BIG 3 (n = 451) in both groups. The 2 groups were similar in distribution of patients among the BIG 1 (\( P = .78 \)), BIG 2 (\( P = .41 \)), and BIG 3 (\( P = .65 \)) categories. Table 2 highlights the demographics of the study population.

In terms of findings on the initial CT scan of the head, subdural hematoma (307 patients [38.6%]) followed by subarach-
noid hemorrhage (273 patients [34.3%]) were the most common types of ICH in the study population. A total of 491 patients (61.7%) had a skull fracture, of which 290 (59.1%) had a displaced skull fracture. There was no difference in the type of ICH before and after implementation of BIG.

Table 3 highlights the findings of the initial CT scan of the head in the study population.

The overall compliance rate with BIG at our center following their implementation was 85.5%. The compliance rate for BIG 1 was 91.6%; for BIG 2, 39.2%; and for BIG 3, 100%.

During the study, 649 patients received neurological consultations and 636 patients received RHCT scans. There was a 19.0% reduction in neurological consultations after implementation of BIG (post-BIG group, 273 patients [71.7%]; pre-BIG group, 376 patients [90.6%]; \( P < .001 \)). Patients who were treated after implementation of BIG were less likely to get an RHCT scan compared with patients who were treated before implementation of the guidelines (post-BIG group, 255 patients [66.9%]; pre-BIG group, 381 patients [91.8%]; \( P < .001 \)). The overall rate of neurological intervention was 15.1% (\( n = 120 \)). There was no difference in the rate of neurological intervention before and after guideline implementation (pre-BIG group, 59 patients [14.2%]; post-BIG group, 61 patients [16.0%]; \( P = .48 \)). Similarly, there was no difference in findings regarding the rate of progression on RHCT (pre-BIG group, 59 patients [14.2%]; post-BIG group, 41 patients [10.8%]; \( P = .14 \)), neurological intervention based on RHCT (pre-BIG group, 8 patients [1.9%]; post-BIG group, 12 patients [3.2%]; \( P = .27 \)), or discharge GCS score (median [interquartile range] for post-BIG group, 15 [14-15]; pre-BIG group, 15 [14-15]; \( P = .88 \)) before and after BIG implementation (Table 4).

After implementation of BIG, there was a 9.3% reduction in the hospitalization rate for TBI. Patients who were treated after implementation of BIG were less likely to require hospi-
tal (post-BIG group, 330 [86.6%]; pre-BIG group, 398 [95.9%];
P < .001) or ICU admission (post-BIG group, 202 [53.0%]; pre-
BIG group, 257 [61.9%]; P = .01) and had shorter hospital
lengths of stay (post-BIG group, 6.1 [4.8] days; pre-BIG group,
6.1 [4.8] days; P = .03) compared with patients who were
treated before BIG implementation. Implementation of BIG was
associated with lower mean hospital costs of $4772 per pa-
tient (P = .03) (Table 4).

On subanalysis of patients from the BIG 1 category, there
was a significant reduction in RHCT scans (pre-BIG group, 59
[67.8%]; post-BIG group, 6 [7.2%]; P < .001), neurological con-
sultations (pre-BIG group, 76 [87.4%]; post-BIG group, 7 [8.4%];
P < .001), hospitalizations (pre-BIG group, 68 [78.1%]; post-
BIG group, 42 [50.6%]; P < .001), and ICU admissions (pre-
BIG group, 24 [27.5%]; post-BIG group, 6 [7.2%]; P = .001) follow-
ing implementation of BIG (Table 5).

### Discussion

At most centers, any patient with a TBI is admitted to the hos-
pital and ICU for repeated imaging and neurological consul-
tation. However, most cases of TBI are managed nonopera-
tively, and neurological consultation or repeated imaging
alone does not alter the course of management.9,10 Moreover,
admiring every patient with TBI for repeated imaging and
and neurological consultation incurs unnecessary radiation
exposure, requires allocation of personnel, and puts a sub-
stantial burden on the neurological services. Our center has
been pushing to reserve the use of repeated imaging and con-
sultation for only the patients with TBI who require it. How-
ever, before formulation of BIG, no practice guidelines were
available for the management of nonoperative TBI by acute care
surgeons. The implementation of BIG standardized the man-
gagement protocols for nonoperative TBI, resulting in a major
paradigm shift in the treatment of these patients exclusively
by acute care surgeons at our center.

There are 2 main findings of our study. First, with the
implementation of BIG, we were able to reduce unnecessary
neurological consultations, hospital admissions, and RHCT
scans. Second, there was no difference in the outcomes of pa-
tients who were treated before and after the implementation
of BIG. We believe that implementation of BIG is safe and cost-
effective in standardizing the practice of nonoperative care for
patients with TBI.

The BIG protocol was developed and implemented at our
level I trauma center in collaboration with our neurological
colleagues. Our center has robust 24-hour on-call neurosur-

### Table 4. Patient Outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-BIG Group (n = 415)*</th>
<th>Post-BIG Group (n = 381)*</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary outcomes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RHCT</td>
<td>381 (91.8)</td>
<td>255 (66.9)</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Neurosurgical consultation</td>
<td>376 (90.6)</td>
<td>273 (71.7)</td>
<td>&lt;.001b</td>
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<tr>
<td>Secondary outcomes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progression on RHCT</td>
<td>59 (14.2)</td>
<td>41 (10.8)</td>
<td>.14</td>
</tr>
<tr>
<td>Neurosurgical intervention based on RHCT</td>
<td>8 (1.9)</td>
<td>12 (3.2)</td>
<td>.27</td>
</tr>
<tr>
<td>Neurosurgical intervention</td>
<td>59 (14.2)</td>
<td>61 (16.0)</td>
<td>.48</td>
</tr>
<tr>
<td>Discharge GCS score, median (IQR)</td>
<td>15 (14-15)</td>
<td>15 (14-15)</td>
<td>.88</td>
</tr>
<tr>
<td>Hospitalization</td>
<td>398 (95.9)</td>
<td>330 (86.6)</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Hospital LOS, mean (SD)</td>
<td>6.1 (4.8)</td>
<td>5.4 (4.5)</td>
<td>.03b</td>
</tr>
<tr>
<td>ICU admission</td>
<td>257 (61.9)</td>
<td>202 (53.0)</td>
<td>.01b</td>
</tr>
<tr>
<td>ICU LOS, mean (SD)</td>
<td>3.8 (3.2)</td>
<td>3.5 (3.1)</td>
<td>.22</td>
</tr>
<tr>
<td>Mortality</td>
<td>69 (16.6)</td>
<td>62 (16.3)</td>
<td>.89</td>
</tr>
<tr>
<td>30-d Readmission</td>
<td>37 (8.9)</td>
<td>31 (8.1)</td>
<td>.69</td>
</tr>
<tr>
<td>Hospital costs per patient, mean (SD), $</td>
<td>14 926 (30 518)</td>
<td>10 154 (27 201)</td>
<td>.03b</td>
</tr>
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</table>

### Table 5. BIG 1 Subanalysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-BIG Group (n = 87)</th>
<th>Post-BIG Group (n = 83)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHCT</td>
<td>59 (67.8)</td>
<td>6 (7.2)</td>
<td>&lt;.001a</td>
</tr>
<tr>
<td>Progression on RHCT</td>
<td>3 (3.4)</td>
<td>1 (1.2)</td>
<td>.33</td>
</tr>
<tr>
<td>Neurosurgical intervention based on RHCT</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Neurosurgical intervention</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Neurosurgical consultation</td>
<td>76 (87.4)</td>
<td>7 (8.4)</td>
<td>&lt;.001a</td>
</tr>
<tr>
<td>Hospitalization</td>
<td>68 (78.1)</td>
<td>42 (50.6)</td>
<td>&lt;.001a</td>
</tr>
<tr>
<td>ICU admission</td>
<td>24 (27.5)</td>
<td>6 (7.2)</td>
<td>.001a</td>
</tr>
<tr>
<td>Mortality</td>
<td>0</td>
<td>0</td>
<td>&gt;.99</td>
</tr>
</tbody>
</table>

Abbreviations: BIG, Brain Injury Guidelines; ICU, intensive care unit; RHCT, repeated computed tomographic scan of the head.
* Values are presented as number (percentage) of patients unless otherwise indicated.
b Statistically significant.
tional survey, more than 75% of emergency department directors reported a shortage of neurosurgeons.20 BIG can help reserve this limited resource for severely injured patients. Moreover, implementation of BIG nationwide can help reduce millions of dollars in hospital costs.31 Protocols for hospital admission in mild TBI should be redefined. Clinical deterioration during the 6-hour period of observation should be used as a guide to hospital admission, neurosurgical consultation, and further imaging in cases of mild TBI.22,23

The BIG protocol was implemented at a level I trauma center with a 24-hour on-call neurosurgical service. Therefore, we recommend that generalization of our findings should be done in this context. Our study is limited by the fact that we did not assess for long-term outcomes in our study patients, such as the Extended Glasgow Outcome Score or Functional Independent Measure. Variables not included in the BIG protocol are still an area of active debate, such as platelet transfusion in patients with brain injury who received anticoagulant therapy. We did not perform a robust cost analysis and only reviewed overall hospital costs. However, despite these limitations, we demonstrate effective implementation of BIG for the treatment of patients with TBI.

Conclusions

Implementation of BIG is safe and cost-effective. The BIG protocol standardizes the treatment of patients with TBI without the need for neurosurgical consultation and unnecessary imaging. It is an important contribution to the growing body of evidence demonstrating the extended utility of acute care service. Establishing a national, multi-institutional study implementing the BIG protocol is warranted.

REFERENCES

3. Hoyt DB, Holcomb J, Abraham E, Atkins J, Sopko G, Working Group on Trauma Research. Working Group on Trauma Research Program summary report: National Heart Lung Blood Institute (NHLBI), National Institute of General Medical Sciences (NIGMS), and National Institute of Neurological Disorders and Stroke (NINDS) of the
use beds, inconvenience other patients, and increase health costs. We can do better. Acute care surgeons are trained, capable, and, most importantly, immediately available to manage such patients.

There is much to be desired in the Joseph et al study.1 The primary outcome was compliance with the guidelines (rate of neurosurgical consultations and repeated head CT scans) when it should have been adverse events because of the absence of a neurosurgeon. The authors found that the pre- and post-BIG periods were generally equally safe but Joseph et al did not address specific events. Furthermore, the main effect of the guidelines was in the BIG 1 type of injuries, which was a good start but far from the optimal target, given that BIG 1 injuries represented only 21% of the examined sample size. With fewer than 5% of patients with head injuries requiring neurosurgical intervention,4 the real need for neurosurgical consultations seemed to be lower than currently believed. The following message from this study relates to the way we practice medicine: subspecialty expertise is often called not for the patient’s advantage but for administrative, medicolegal, or financial reasons. Our abundant resources will become scarce when we use them without reason. We can do better. The importance of adhering to BIG for small head injuries is really big!

Brain Injury Guidelines for Small Head Injuries

George C. Velmahos, MD, PhD, MEd

In the Joseph et al article,3 the authors proposed locally produced Brain Injury Guidelines (BIG), which allowed the acute care surgery team to manage patients with mild head injuries without neurosurgical consultation. All moderate and severe head injuries were managed per routine. The decision to avoid calling the neurosurgeon for patients with intact neurologic examinations and either no (BIG 1) or minimal (BIG 2) space-occupying lesions on computed tomography (CT) predictably produced what we know to be true. There were fewer repeated head CT scans, shorter hospital stays, and reduced hospitalization costs.

Neurosurgeons are extremely valuable but also overstretched. Neurosurgical consultations for bread-and-butter head injuries do not offer much more than routine recommendations and are primarily for legal coverage for those requesting the consultation. Delaying discharge decisions while waiting for a consultant or substituting a consultant’s presence with repeated head CT scans5 and other tests6 are common. Even worse, in hospitals without a neurosurgeon, patients may be transferred to trauma centers, where they use beds, inconvenience other patients, and increase health